Alaska Department of Fish and Game
Division of Wildlife Conservation
March 1999

Spruce Beetle Effects on Wildlife

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Research Performance Report
Federal Aid in Wildlife Restoration
1 January 1997–30 December 1998
Grant W-27-1, Study 1.53

This is a progress report on continuing research. Information may be refined at a later date.

RESEARCH PROGRESS REPORT

STATE: Alaska **STUDY:** 1.53

GRANT: W-27-1

STUDY TITLE: Spruce Beetle Effects on Wildlife

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PERIOD: 1 January 1997–31 December 1998

SUMMARY

During the 1998 season, we conducted 594 point counts of breeding birds in Kenai lowland forests, using the variable circular plot method. Townsend's Warbler (*Dendroica townsendi*) and Golden-crowned Kinglet (*Regulus satrapa*) may be most negatively affected by habitat changes caused by bark beetles (*Dendroctonus rufipennis*). Further, these two species are essentially absent from salvage-logged areas, and Townsend's Warblers are rare in mixed birch (*Betula papyrifera*)–spruce (*Picea glauca*) forest. The Three-toed Woodpecker (*Picoides tridactylus*) appears to benefit from bark beetle infestation but declines when the infestation subsides and availability of beetle larvae decreases. Solitary Sandpiper (*Tringa solitaria*), an easily overlooked species, may be affected by spruce mortality and/or logging. Species diversity in selectively logged stands is maintained in direct proportion to remaining tree densities, with a shift toward species preferring open habitats. Selectively logged mixed birch–spruce forests maintained higher bird diversity than logged spruce stands because of greater tree density and vegetative diversity.

Northern red-backed voles (*Clethrionomys rutilus*) accounted for 89% of 532 individuals collected in 1998. Preliminary analysis indicated the highest northern red-backed vole populations inhabited pure spruce stands infested with bark beetles.

Key Words: berries, breeding birds, habitat, logging, moose, small mammals, Spruce beetle, vegetation.

CONTENTS

BACKGROUND

A current epidemic of spruce bark beetle (*Dendroctonus rufipennis*) has killed white spruce (*Picea glauca*) on more than 2.5 million acres in Alaska. Approximately 500,000 acres of new and ongoing infestation is present on the Kenai Peninsula. This scale of infestation has not occurred in more than 100 years, and the level of salvage logging associated with it is unprecedented. However, the effects of canopy reduction by bark beetles and/or salvage logging on wildlife are poorly documented.

Spruce beetles primarily attack white spruce by boring through the bark, feeding, and breeding in the phloem. Their entry through the bark introduces a bluestain fungus (*Ceratocystis*) that causes tree mortality. Spruce beetles are endemic in Alaskan forests, preferring windthrown or other recently downed spruce. In the absence of downed spruce, or when weather favors high populations of beetles, the beetles attack old, large-diameter spruce (Holsten 1990). In severe outbreaks, the beetles may move into small-diameter trees when larger trees have been eliminated. In the current epidemic, some areas have lost most spruce larger than 10–15 cm diameter at breast height (dbh).

In response to beetle-killed spruce forests, private landowners and Native corporations in south-central Alaska have developed large-scale salvage logging operations. State and federal agencies are following suit as quickly as legally possible. Under the Timber Salvage Bill passed by Congress in 1995, the U.S. Forest Service and other federal land managers are required to salvage timber.

Beetle infestation and logging potentially affect structure, productivity, and composition of understory plants used by small mammals for food and cover. Beetle infestation, however, is unique from logging disturbances in that (1) large trees in older stands are selectively killed; (2) understory and soil layers are not directly affected by disturbance; (3) plants and nutrient cycling respond slowly; (4) repeated epidemics help maintain a mosaic of uneven-aged stands; and (5) tree mortality is usually moderate with about 50% of the canopy cover altered (Stone and Wolfe 1996). Small mammals can adapt to some short-term environmental modifications (Bourliere 1975). This ability, coupled with their sheer numbers and the amount of energy they represent in the system, enables small mammals to have significant effects on vegetation consumption, forest decomposition, and predator dynamics (Johnson et al. 1990; Stoddart 1979; Maser et al. 1978).

In a Kenai Peninsula small mammal study (1979), Bangs found a single species, the northern red-back vole (*Clethrionomys rutilus*), dominated the small mammal community. However, northern red-backed voles were less abundant on mechanically disturbed sites, as were berries, mosses, lichens, and mushrooms on which voles depend. Additionally, a recent vegetation study on the Kenai Peninsula showed that *D. rufipennis* infestation and fire increased the abundance of bluejoint reedgrass (*Calamagrostis canadensis*) and fireweed (*Epilobium angustifolium*), while many of the northern red-backed voles' primary food species remained the same or slightly decreased in abundance (Holsten et al. 1995).

A decrease in forest overstory has been shown to increase light and nutrients, making them available to understory plants (Stone and Wolfe 1996, Holsten et al. 1995). An increase in understory vegetation decreases predation on small mammals by decreasing visual detection and providing more opportunities for escape. However, an increase in light to the forest floor, or mechanical disturbance, may decrease the abundance of moss, lichens, and other species used by small mammals for food and thermal cover.

OBJECTIVES

The interagency Forest Ecology Study Team identified the determination of wildlife effects as first priority before scientifically based management of beetle-impacted forests can be developed. They identified effects of canopy reduction on breeding birds, small mammals, moose browse, and production of berries important to wildlife as priorities for research. Alaska Department of Fish and Game adopted these research priorities for this study.

BREEDING BIRDS

Determine differences in breeding bird density, composition and diversity between infested, logged, and undisturbed stands.

H_o: Breeding bird densities in beetle-killed, logged, and undisturbed stands are equal.

H_o: Diversity of breeding birds in beetle-killed, logged, and undisturbed stands is equal.

SMALL MAMMALS

Determine differences in small mammal density, recruitment, or survival between infested, logged, and undisturbed stands.

H_o : Small mammal densities in beetle-killed, logged, and undisturbed stands are equal.

H_o : Small mammal survival in beetle-killed, logged, and undisturbed stands is equal.

H_o : Small mammal recruitment in beetle-killed, logged, and undisturbed stands is equal.

MOOSE BROWSE

Determine if overstory reduction by beetles or logging reduces productivity of browse species.

H_o : Browse densities in beetle-killed, logged, and undisturbed stands are equal.

H_o : Browse production in beetle-killed, logged, and undisturbed stands is equal.

BERRIES

H_o : Densities of berry-producing species in beetle-killed stands, logged stands, and undisturbed stands are equal.

H_o : Berry production by species in beetle-killed stands, logged stands, and undisturbed stands is equal.

METHODS

STUDY AREA

The study area is the Kenai Lowlands, bounded by Skilak Lake and Swanson River to the north and Kasilof River to the south. The study examines effects of overstory reduction by beetles and by logging on wildlife in 2 upland habitat types within the lowlands—spruce and mixed spruce-hardwood. Spruce stands being studied are composed of 90%, or more, white spruce or white spruce/Lutz spruce hybrid. Mixed stands being studied have 40 to 60% spruce; the remainder of the trees are hardwoods—paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*), and/or black cottonwood (*Populus triohcarpa*). Observations of infested forest are limited to those stands that experienced canopy mortality by bark beetles 3–5 years before the study began. Observations of logged stands are limited to stands logged 3 to 5 years before the study in a way most common to private operations on the Kenai Peninsula. Undisturbed stands included in the study are those which have not experienced major disturbance, including fire, for at least a century. All study plots are between 60 and 250 m elevation, located on flat ground or slopes less than 5 %, and dominated by trees >100 years old.

BREEDING BIRDS

In 1998 we conducted forest bird surveys during the breeding season from 26 April to 24 June. This is the period when nearly all breeding for landbird species takes place in Southcoastal Alaska. Surveys were conducted during 4 nonoverlapping periods to distinguish between singing periods for early and late arriving species as follows: 26 April–7 May, 13–21 May, 26 May–6 June, and 11–24 June 1998.

Twenty-two 36-ha breeding bird survey plots (600 m x 600 m) were randomly located within 4 treatments in each of 2 forest types, mixed spruce-deciduous and pure spruce. Treatments were classified on the amount of spruce mortality as (1) none to light (0–10%), (2) moderate (11–40%), and (3) heavy (>40%). A fourth treatment in each forest type was selectively logged stands, presumed to have had heavy spruce mortality prior to logging. Three replicate plots were established for each treatment type, except the moderate and logged mixed forest treatments for which only 2 replicate stands could be found, a total of 22 plots (Table 1). Survey plots for each treatment both within and between forest types were matched as closely as possible with respect to slope, aspect, elevation, understory, and stand age, and within habitat composition of stand. Two general age classes of stands are prevalent on the study area. Older mature stands that established in the late 1800s were selected for treatments. Selected mixed forest stands were approximately a 60:40 mix of white spruce (*Picea glauca*) and deciduous, predominantly paper birch (*Betula papyrifera*). Selected spruce stands tended to be greater than 90% white spruce/Lutz spruce (*P. glauca x sitchensis*).

Within each survey plot, 9 census stations were systematically located in a 3 x 3 matrix grid. Each station was 200 m from any adjacent station and 100 m from the perimeter of the plot, except for the center station that was 300 m from the plot perimeter. We used aerial photographs to center plots within stands and, to the extent possible, to maintain a minimum buffer of 150 m from ecotones. Birds were surveyed using the variable circular plot method.

We visited plots once each survey period. Observers and starting points were rotated to balance the effects of observer and diurnal variability in detections. Surveys were begun as close to 15 minutes after sunrise as possible and continued until each station had been censused for 8 minutes. Observers recorded the number, behavior (singing, calling, drumming, flying), sex, and type of detection (aural, visual, or both) of birds of each species and the distance of the bird from the station center when first detected. Birds were recorded within 10-m bands to 100 m and within 25-m bands from 100 m out to an unlimited distance.

We are describing vegetation characteristics relevant to bird habitat according to protocol established by the National Biological Survey's Alaska Neotropical Migratory Bird Project (ANMBP) to enable comparison with data collected by ANMBP in other regions of the state.

Results from plot counts will be analyzed for density of singing males using Program Distance and ANOVA and other nonparametric tests. These data will be incorporated into a regression analysis with vegetation data to develop a model for breeding bird density by species relative to spruce mortality.

Nocturnal owl surveys were conducted from 17 March to 1 May 1998 when owls were establishing territories and breeding. Using the variable circular plot method, we conducted these surveys independently of point count censuses because owls are not normally active postdawn when censuses were conducted. The owl breeding season also occurs earlier than that of most other forest bird species, further necessitating a separate sampling effort. Six species of owls are known to breed in Southcoastal Alaska: Great Horned Owl (*Bubo virginianus*), Northern Hawk Owl (*Surnia ulula*), Great Gray Owl (*Strix nebulosa*), Short-eared Owl (*Asio flammeus*), Boreal Owl (*Aegolius funereus*), and Northern Saw-whet Owl (*Aegolius acadicus*). The Snowy Owl (*Nyctea scandiaca*) occurs infrequently in Southcoastal Alaska during the non-breeding season.

Duel objectives of nocturnal owl surveys were (1) to examine habitat use by forest owls and (2) to test field methods for censusing and monitoring owl populations in Alaska. Four species were targeted by nocturnal surveys: Great Horned, Great Gray, Boreal, and Northern Saw-whet Owl. Snowy and Short-eared Owls inhabit open country and are not effectively sampled by nocturnal roadside surveys. The Northern Hawk Owl is active during twilight and daytime in semi-open country.

Five routes following forest access roads were selected on the study area. Routes were 5 miles (8 km) in length with listening stations every .5 mile (.8 km), totaling 10 stations per route. An attempt was made to maintain the same observer for a route for consistency and in order to reduce observer variability, assuming these routes may be established for long-term monitoring similar to the North American Breeding Bird Survey. We surveyed routes in opposite order from the previous survey to vary the start times at each station. Each station was censused twice in a given night to adequately census different species that vary in times of peak calling activity. After the first pass through the stations, observers paused 15 minutes, then resampled the stations in reverse order. Census routes were begun at local sunset and continued until completion, usually 4 to 5 hours. Listening at each station was for 8 minutes. Routes were surveyed once a week, weather permitting. Acceptable weather conditions included little or no precipitation and light or no wind. We recorded starting time of observation, time period (first 5 minutes or last 3 minutes), distance, and direction to calling owls.

Census routes were established to sample both mixed and spruce forest types at varying levels of spruce bark beetle infestation. The Swan Lake Road route passes through lightly infested mature mixed forest, while the 1200 Road routes are in mixed forest with moderate to heavy infestation and in salvage-logged areas. The East Road route passes through lightly infested spruce forest with some open muskeg. The latter has since been salvage-logged to a large degree. The Oil Well/5000 Road route is bounded by moderate to heavily infested spruce forest with salvage-logged stands on one side and Deep Creek canyon on the other.

SMALL MAMMALS

We used mark–recapture techniques to estimate small mammal population abundance. We obtained temporal, behavioral, or individual heterogeneity in capture probabilities by simultaneously capturing and marking a sufficient number of individuals (Rexstad 1996). This method of capture–recapture will allow survival and recruitment to be evaluated as factors of abundance, which in turn will provide a better predictive population model.

The small mammal trapping design was modified in 1998 to provide better comparisons between stands. Each site was trapped 4 times May through August to include the lowest population level (early spring), reproduction rates, and juvenile survival (early and midsummer), and the population peak (late summer). This schedule also provided data for both endpoints of the intervals being used to estimate survival and abundance (Rexstad 1996).

All small mammal sampling was based on randomly located 90-m square grids having 100 traps systematically spaced at 10-m intervals across the grid. All grids were surrounded by at least a 30-m buffer to control for possible edge effects. Since natural phenomena like spruce bark beetle outbreaks cannot be replicated, this study focused on differences between forest stands instead of treatment effect.

Undisturbed, beetle-killed stands (60-90% canopy mortality at least 3 years before the study) and logged stands in the pure spruce habitat type were each sampled with 3 replications. In mixed, we sampled the spruce-deciduous habitat type, 3 logged stands but only 2 beetle-killed stands, because accessible beetle-killed stands were limited. All stands within either habitat type were of the same approximate elevation, aspect, age (established in late 1800s), and understory composition prior to disturbance

As dramatic fluctuation in small mammal populations can occur within even a few weeks, all replications within each stand were trapped simultaneously. Stands trapped simultaneously were spruce-control and spruce-logged, spruce-infested and mixed-logged, with mixed-infested trapped separately.

All traps were set and baited with rodent food cubes and bedding the evening of day 0. Each trap was then checked 2 times daily for 5 days. We marked animals by implanting a subcutaneous Passive Integrated Transponder (PIT) tag. The individual PIT code, weight, sex, reproductive status, approximate age, and location of capture were recorded for each animal before release. The PIT code, weight, reproductive status, and location of capture were subsequently recorded for all recaptures. Food and bedding were changed after each capture.

We sampled vegetation with 20 2 x 30-m belt plots on each trap grid. Start points for each plot were systematically located along 4 base transects, evenly distributed across the trapping grid and buffer zone. Direction of belt plot layout was determined by random selection of direction (0–45^{O}) from base transects. We collected vegetation data in July after herbaceous vegetation had matured.

Overstory cover by species in each plot was measured with a single point densiometer at every third meter along the length of each belt plot. Diameter at breast height (dbh) of the first 2 individuals of each tree species in the plots was measured using calipers. Tree density was estimated by counting all trees greater than 2.5 cm dbh. Tree regeneration was estimated by counting all trees and seedlings less than 2.5 cm dbh.

Stems of berry producing species taller than 50 cm were counted within 1 x 30-m belts within each plot. The total number of berries was then counted on all stems taller than 50 cm.

We determined understory groundcover in 0.25-m quadrats, located at random locations within each plot, assigning cover classes 1–6 (Daubenmire 1959) to all species. All berries within each quadrat were counted; all units of large woody debris (logs or slash piles) lying across transects were counted as an index to availability of that form of cover. Moss and litter depths were measured every 3 meters along the length of the belt plots.

MOOSE BROWSE

We sampled breeding bird and small mammal plots for browse productivity and quality to relate browse characteristics to associated overstory and understory conditions. We are determining stem densities of all browse species greater than 50-cm height by count in 2 x 30-m plots selected as described under "Small Mammals." Current annual growth (CAG) of all species will be determined by clipping all current annual twigs between 50 and 250-cm height on a stem of each species nearest the 0 and 30-m points on each transect. Number of twigs and their weights and lengths will be recorded from each clipped stem. We will determine crude protein and in vitro digestibility of a subsample of CAG from each site.

BERRIES

We estimated densities of berry producing species and berry production important to bears according to procedures outlined under "Small Mammals." We determined mean dry weight of berries from each replication.

RESULTS AND DISCUSSION

BREEDING BIRDS

Using the variable circular plot method, we conducted 66 plot surveys during the 1998 breeding season, for a total of 594 point counts. Except for the last survey period, we were not able to survey all replicate treatment plots in the first 3 survey periods due to (1) bureaucratic restrictions on hiring qualified technicians and (2) inaccessibility of some plots due to snow or high water during the first survey period.

During 1997–98 we observed 97 bird species in all habitats of the study area (Table 2). Identification of 2 additional species, Peregrine Falcon (*Falco peregrinus*) and Great Gray Owl were unconfirmed. Two other species, Snowy Owl and Say's Phoebe (*Sayornis saya*) were observed near the study area. Additional rare or occasional species are expected to occur in appropriate habitats. Table 2 summarizes bird species presence by plot.

Preliminary analysis indicates that 2 species, Townsend's Warbler (*Dendroica townsendi*) and Golden-crowned Kinglet (*Regulus satrapa*), may be most negatively affected by habitat loss in areas with heavy spruce mortality. Further, these 2 species are essentially absent from salvage-logged areas, and Townsend's Warblers do not occur in any significant numbers in mixed-forest habitats. Stands with live, mature spruce may be critically important in the maintenance of these 2 species, especially Townsend's Warbler. Other species such as the Northern Goshawk (*Accipiter gentilis*) may also be critically impacted by habitat loss from spruce mortality and salvage-logging. Only the Three-toed Woodpecker (*Picoides tridactylus*) seems to benefit from

spruce bark beetle-infested stands. However, their numbers begin to decline in stands several years after spruce mortality when trees have been "worked over" and beetle larvae are no longer present.

At least one Solitary Sandpiper (*Tringa solitaria*) was heard singing on or by nearly every plot. This species was usually heard singing near wet forest gaps 10–20 m wide. Solitary Sandpipers utilize deserted, surveyed, even new, passerine nests often of Rusty Blackbird (*Euphagus carolinus*), American Robin (*Turdus migratorius*), and Gray Jay (*Perisoreus canadensis*) in conifers or occasionally deciduous trees (Ehrlich, et. al. 1988). Because of their biology, spruce mortality and salvage logging may affect them. Their low density on the study area may make interpretation difficult. Nevertheless, this may be an easily overlooked species.

Preliminary analysis also indicated that species diversity is maintained in selectively logged stands directly proportional to remaining stem densities, with a shift toward more swallows (*Hirundinidae*), thrushes (*Turdidae*), and sparrows (*Emberizidae*)—species that prefer relatively open habitats. Selectively logged mixed forest stands maintained higher bird diversity than selectively logged spruce stands because of higher stem densities and vegetative diversity provided by deciduous tree species left unlogged.

Three species of owls were recorded during nocturnal surveys: Great Horned, Boreal, and Saw-whet (Table 2). Great Horned Owls called most actively within approximately 2 hours of sunset, while the smaller Boreal and Saw-whet Owls began calling later and continued later into the evening. Calling by Great Horned Owls diminished in April, while Boreal Owls were actively calling until mid-April. Saw-whet calling activity began in earnest at the beginning of April and declined in late April, yet continued into May.

Frequently poor weather conditions throughout the census prevented survey routes from being sampled consistently each week or sometimes prevented completion of a survey evening. On 17 March snow cover was 0.5–1.0 m depth, depending on elevation, and evening temperatures were 0 to -7° C. Patches of snow as deep as 1.0 m were still present on 1 May, but evening temperatures were +2 to +7° C.

SMALL MAMMALS

Northern red-backed voles accounted for 89% of 532 individuals collected in 1998 (Table 3) and 88% of the 351 individuals collected in 1997 (Table 4). Few shrews (*Sorex* sp.*)* were captured, primarily in mixed and spruce-logged sites in 1998. A species of *Microtus* was captured on the spruce-logged sites in 1997, but no captures were made in 1998 (Table 3). Red squirrels (*Tamiasciurus hudsonicus*) were incidental in 1997, and no captures were made in 1998 (Table 4). Weasels (*Mustela* sp.) were caught in undisturbed and beetle-killed spruce sites and in logged spruce–deciduous sites in 1998 (Table 3). Preliminary multiple comparison ANOVA (SAS Inst. Inc. 1985) results indicate the highest northern red-backed vole populations were found in pure spruce stands infested with bark beetles (Table 3). Because of the difference in time, 1997 trapping dates must be taken into consideration when comparing treatments and years.

MOOSE BROWSE

Harvested sites scarified during harvest or within the first snow-free period following harvest continued to favor regeneration of hardwoods in the Kenai lowlands.

BERRIES

Berry production variability between belt plots was too great for estimation of production by methods we used.

RECOMMENDATIONS

BREEDING BIRDS

Owl surveys should be repeated in 1999, beginning approximately 1 March to more adequately sample the Great Horned Owl breeding season. Surveys should be continued until approximately 30 April 1999 when Saw-whet Owl calling diminishes. Assessment of habitats where owls were detected should be completed in May 1999.

A bibliography for Alaskan owl species should be prepared for distribution.

SMALL MAMMALS

Small mammal (particularly rodent) populations vary from habitat to habitat. Seasonal population patterns emerge as a function of breeding cycles. Yearly cycles are related to changes in weather, resource availability, and pressure from predators. Multiannual cycles may occur due to lagged response to environmental changes or in response to population density (French et al 1975; Smith et al 1975; Flemming 1979; Southern 1979; Batzli 1991).

In Alaska, several small mammal studies have found what appears to be a 3-year cycle for most arvicolines, northern red-backed voles in particular. Populations reach a peak, crash, then begin to rise again. Theories on the cause of the cycle are inconclusive and range from food shortage and overpopulation to snowless winters that prevent the animals from building tunnels to food caches (West 1979; Furtsch 1995; Staples 1995; Rexstad 1996).

Changes in study design between 1997 and 1998 make an additional trapping season necessary to rule out any year effects in 1998 data. Due to limited availability of suitably infested and undisturbed, mixed hardwood–spruce habitat, and constraints on time and logistics, it is recommended the 1998 trapping schedule be maintained only for pure spruce sites during the summer of 1999.

Recent burns and logged areas are considered habitat sinks for many small mammals. These sinks provide an important dispersal area for juvenile or less dominant animals when densities in optimum habitat become too high (Sullivan 1979). The order in which optimal and suboptimal habitats are filled and abandoned may provide important clues to understanding the effects of management actions on relations between small mammals and their habitat (Krohn 1992).

We recommend that beginning in October 1999 a yearlong effort of trapping for a 7-day interval every 3 months be implemented. Population data from all seasons will help determine survival rates and whether each treatment is providing a habitat sink, or source, for small mammals. Having yearlong small mammal population data would also be an important base for extending research from arvicolines to other mammals, such as hares (*Lepus americanus*), porcupines (*Erethizon dorsatum*), and predators such as birds of prey, weasels, coyotes (*Canis latrans*), fox (*Vulpes vulpes*), and lynx (*Felis lynx*).

MOOSE BROWSE

Harvested sites should be scarified during harvest or within the first snow-free period following harvest to favor regeneration of hardwoods, and Aspen and cottonwood should be felled in conjunction with spruce harvest to stimulate suckering (Collins and Schwartz 1998).

BERRIES

We believe it is beyond the scope of this study to accurately assess the berry resource relative to wildlife, given the degree of variability we have observed. We recommend a more extensive sampling scheme that incorporates transects of sufficient length to reduce sample variability. Such sampling is not compatible with our other vegetation sampling procedures, and it will probably require unique effort.

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Table 1 Breeding bird survey plots

Habitat Type	Plot Number	1997 Plot Number	Township	Range	Section	Name	Access	Ownership[1]	Year Logged
Mixed-Light	1	5	T.7N.	R.8W.	6	Lake Sabaka	Swan Lake Road	KENWR	
Mixed-Light	2	6	T.7N.	R.8W.	8	Waterfowl Lake	Swan Lake Road	KENWR	
Mixed-Light	3		T.7N.	R.9W.	1	Cashka Lake	Swan Lake Road	KENWR	
Mixed-Moderate	4		T.1S.	R.14W.	36	Lower Ninilchik River 1	Brody Road	CIRI	
Mixed-Moderate	5		T.1S.	R.14W.	36	Lower Ninilchik River 2	Brody Road	CIRI	
Mixed-Moderate[2]	6								
Mixed-Heavy	7		T.2N.	R.12W.	32,33	Clam Gulch	Sterling Highway	NNAI/State/UA	
Mixed-Heavy	8		T.1N.	R.11W.	4	Border Lake 1	Falls Creek Road/Border Lake Trail	CIRI	

Habitat Type	Plot Number	1997 Plot Number	Township	Range	Section	Name	Access	Ownership[1]	Year Logged
Mixed-Heavy	9		T.2N.	R.11W.	32	Border Lake 2	Falls Creek Road/Border Lake Trail	CIRI	
Mixed-Heavy	Alternate	1	T.1N.	R.12W.	32	Ninilchik River	1200 Road/Small Lakes Tract	CIRI	
Mixed-Heavy	Abandoned	2	T.1S.	R.12W.	6	Ninilchik River Bend	1200 Road/Small Lakes Tract	State	
Mixed-Logged	10	4	T.1N.	R.12W.	3	Swan Lake	Falls Creek Road	CIRI	1993
Mixed-Logged[2]	11	3	T.2N.	R.12W.	36	Crooked Creek	Falls Creek Road	CIRI	1993
Mixed-Logged	12		T.1N.	R.12W.	11	Upper Ninilchik River	Falls Creek Road	CIRI	1993
Spruce-Light	13	13	T.3S.	R.14W.	12,13	Stariski Creek	7000 Road	Borough Selection	
Spruce-Light	14		T.3S.	R.14W.	9,16	Happy Valley	Happy Valley Road	CIRI/Private	
Spruce-Light	15		T.3S.	R.14W.	2,3	East Road	East Road	Borough Selection/Borough	

Table 1 Continued

Habitat Type	Plot Number	1997 Plot Number	Township	Range	Section	Name	Access	Ownership[1]	Year Logged
Spruce-Light	Abandoned	15	T.7N.	R.8/9W.	7,18/12, 13	Dolly Varden Lake	Swanson River Road	KENWR	
Spruce-Moderate	16		T.3S.	R.14W.	2,11	Happy Creek	7000 Road	Borough Selection	
Spruce-Moderate	17		T.2S.	R.14W.	16	Anderson Hill	Sterling Highway	CIRI/State	
Spruce-Moderate	18		T.2S.	R.14W.	14,15	Clam Creek	Deep Creek Farm Road	UA/CIRI	
Spruce-Heavy	19	8	T.1S.	R.11W.	20	Falls Creek Trail	1200 Road	State	
Spruce-Heavy	20	7	T.1S.	R.11W.	1,12	KENWR/Crooked Creek	1200 Road	KENWR	
Spruce-Heavy	21		T.2S.	R.11/12 W.	30/25	Deep Creek Dome	Oil Well Road/5000 Road	CIRI/State	
Spruce-Logged	22		T.3S.	R.14W.	25	Chakok River East	7000 Road	NNAI	1994

Habitat Type	Plot Number	1997 Plot Number	Township	Range	Section	Name	Access	Ownership[1]	Year Logged
Spruce-Logged	23		T.3S.	R.14W.	22,23,26,27	Chakok River West	7000 Road	NNAI	1993
Spruce-Logged	24		T.2S.	R.11W.	18,19	North Fork Deep Creek	Oil Well Road/5000 Road	CIRI/State	1994

[1]Borough =
Kenai Borough
Borough Selection = Kenai Borough Selection Patent Pending
CIRI = Cook Inlet Region, Incorporated
KENWR = Kenai National Wildlife Refuge
NNAI = Ninilchik Native Association, Incorporated
P = Private
State = State of Alaska
UA = University of Alaska
[2]Plot was either not selected or (surveyed
r

Table 2 Breeding bird species list

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Gaviidae*																														
Common Loon																														PO
Family *Podicipediidae*																														
Red-necked Grebe																														PC
Family *Anatidae*																														
Trumpeter Swan																														CR
Canada Goose																														X
Green-winged Teal																														X
Mallard																									X					X
Northern Pintail																														X
Northern Shoveler																														X
American Wigeon																														X
Scaup spp.																														M
Harlequin Duck																														PO,R
Oldsquaw																														M
Surf Scoter																														M
Common Merganser																														PO

Table 2 Continued

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Accipitridae*																														
Osprey																														PO
Bald Eagle							A										X	A				A		A					CY,R
Northern Harrier																														X
Sharp-shinned Hawk													X		X?			X												PO
Northern Goshawk	X												X		X															PA,R
Red-tailed Hawk																					X			A	X?					CO
Rough-legged Hawk																														M
Family *Falconidae*																														
American Kestrel																														X
Merlin				X			X																							PA
Peregrine Falcon[3]																														O
Family *Phasianidae*																														
Spruce Grouse		X		X	X		X			X		X	X	X	X	X	X	X	X	X	X									CE,CR,R
Family *Gruidae*																														
Sandhill Crane																														PC
Family *Charadriidae*																														
Killdeer																														X

Table 2 Continued

Species	Habitat Plots[1]																							Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Scolopacidae*																														
Greater Yellowlegs																														X
Lesser Yellowlegs												X												X						CD
Yellowlegs spp.		X		A				X						X						X										
Solitary Sandpiper		X	X		X							X		X		X		X			X			X						PT
Spotted Sandpiper																														X
Whimbrel																														M
Black Turnstone																														M
Western Sandpiper																														M
Least Sandpiper																														PC
Common Snipe	A	A	A	A	A		A	A	X			A	A	A		A	A		A	A				X		X		A	A	CE
Family *Laridae*																														
Bonaparte's Gull																														PA
Mew Gull							A																							PA
Herring Gull																														X
Glaucous-winged Gull																														X
Arctic Tern																														PA
Family *Alcidae*																														
Murre spp.																														O

Table 2 Continued

Species	Habitat Plots[1]																							Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Strigidae*																														
Great Horned Owl																			X						X	X		X		CR,R
Snowy Owl[4]																														M
Northern Hawk Owl																														CO,R
Great Gray Owl[3]																														O,R
Short-eared Owl[5]																														
Boreal Owl																									X	X	X	X	X	PT,R
Northern Saw-whet Owl																			X							X		X		PT,R
Family *Trochilidae*																														
Rufous Hummingbird[5]																														
Family *Alcedinidae*																														
Belted Kingfisher																														PT
Family *Picidae*																														
Downy Woodpecker										X		X																		CN,R
Hairy Woodpecker		X																												CY,R
Downy/Hairy Woodpecker	X		X	X	X			X	X			X			X	X														
Three-toed Woodpecker	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						CY,R
Black-backed Woodpecker																														PO,R

Northern Flicker[5]																											

Table 2 Continued

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Tyrannidae*																														
Olive-sided Flycatcher	X	X	X					X	X	X		X		X			X													PT
Western Wood-Pewee								X		X		X										X								PT
Alder Flycatcher	X	X	X				X			X		X	X						X				X	X						PT
Say's Phoebe[4]																														CR
Family *Laniidae*																														
Northern Shrike																														PO,R
Family *Corvidae*																														
Gray Jay	X	X	X	X	X		X	X	X	X		X	X			X		X	X	X	X			X						CR,R
Steller's Jay[5]																														
Black-billed Magpie			X																											X,R
Northwestern Crow																														X,R
Common Raven	X		X	X	X		X							X					X	X	A	X		A		X	X			X,R
Family *Hirundinidœ*																														
Tree Swallow																														X
Violet-green Swallow		A	A	A			A		A?					A			A					A	X	A						CO,CF
Bank Swallow			A?																											CO
Cliff Swallow																														X

Swallow spp.					X																						

Table 2 Continued

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Paridae*																														
Black-capped Chickadee	X	X	X				X		X				X								X									X,R
Boreal Chickadee	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X			X						CO,R
Family *Sittidae*																														
Red-breasted Nuthatch	X		X	X	X		X	X	X								X	X												X,R
Family *Certhiidae*																														
Brown Creeper	X	X	X	X	X		X	X	X			X	X	X	X	X	X	X	X	X	X			X				X			CO,CR,R
Family *Troglodytidae*																														
Winter Wren[5]																														
Family *Cinclidae*																														
American Dipper																														PA,R
Family *Regulidae*																														
Golden-crowned Kinglet	X	X	X	X	X		X	X	X				X	X	X	X	X	X	X	X	X									CF,R
Ruby-crowned Kinglet	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X					X	PA

Table 2 Continued

Species	Habitat Plots[1]																								Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Turdidae*																														
Gray-cheeked Thrush																					X			X						PT
Swainson's Thrush	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X		X							PA
Hermit Thrush	X		X	X			X					X	X	X	X	X?	X	X	X		X			X						PT
American Robin	X	X	X	X	X		X		X	X		X		X		X	X			X		X	X	X						PA
Varied Thrush	X	X	X	X	X		X	X	X				X	X	X	X	X	X	X	X	X		X				X			PA
Family *Motacillidae*																														
American Pipit																														M
Family *Bombycilliidae*																														
Bohemian Waxwing[5]																														
Family *Parulidae*																														
Orange-crowned Warbler	X	X	X	X	X		X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X						PA
Yellow Warbler		X								X											X??									X
Yellow-rumped Warbler	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						PA
Townsend's Warbler	X			X	X		X						X	X	X	X	X	X	X	X	X			X						PA
Blackpoll Warbler																								X						X
Northern Waterthrush	X																X													PT

Wilson’s Warbler	X			X		X	X	X				X	X	X		X		X		X		X	X						PT

Table 2 Continued

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Emberizidae*																														
American Tree Sparrow[5]																														
Savannah Sparrow							X												X		X	X	X	X						PA
Fox Sparrow																X														PT
Song Sparrow																														X,R
Lincoln's Sparrow			X	X			X			X		X		X			X	X	X			X	X	X						PA
Golden-crowned Sparrow																	X	X	X			X	X	X						PT
White-crowned Sparrow		X			X					X		X							X			X	X							PA
Dark-eyed Junco	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						CE,CR
Lapland Longspur																														M
Snow Bunting																														M
White-crowned Sparrow		X			X					X		X							X			X	X							PA
Dark-eyed Junco	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						CE,CR
Lapland Longspur																														M
Snow Bunting																														M
Family *Icteridae*																														
Rusty Blackbird																														X

Table 2 Continued

Species	Habitat Plots[1]																						Nocturnal Owl Survey Routes					
	Mixed-Light			Mixed-Moderate			Mixed-Heavy			Mixed-Logged			Spruce-Light			Spruce-Moderate			Spruce-Heavy			Spruce-Logged			Swan Lake Road	1200 Road East	1200 Road West	Oil Well Road	East Road	Breeding Status2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
Family *Fringillidae*																														
Pine Grosbeak			X					X							X					X		X							X,R
Red Crossbill[3]		X																												X,R
White-winged Crossbill	X	X	X	X					X					X																PO,R
Crossbill spp.	X		X		X		X		X							X														
Common Redpoll																				X				X						PO,R
Pine Siskin																														X,R
Common Redpoll/Pine Siskin	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X						
Unknown Fringillidae								X							X			X												

[1]Only those species associated with the habitat of a plot are checked (X = Present, A = Aerial Detection).

[2]O = Observed

X = Possible

Continued

P = Probable: PO = Pair Observation, PT = Permanent Territory, PC = Courtship Behavior, PN = Nest-site Visitation, PA = Agitated Behavior

C = Confirmed: CN = Carrying Nesting Material, CB = Nest Building, CU = Used Nest, CO = Occupied Nest, CD = Distraction Display, CP = Physiological Evidence, CE = Nest With Eggs, CY = Nest With Young, CG = Precocial Young, CF = Carrying Food,

CS = Fecal Sac Removal, CR = Recently Fledged Young, CI = Feeding Recently Fledged Young (USFWS, 1995)

R = Resident

M = Probable Migrant

[3]Identification was uncertain.

[4]Species was observed adjacent to study area.

[5]Species was not observed but is expected to breed in appropriate habitats at low density (i.e., rare in abundance).

Table 3 Individual session captures of small mammals in logged and spruce bark beetle infested mixed hardwood–spruce and logged, infested, and undisturbed pure spruce stands on the Kenai Peninsula, Alaska, 1998

	Treatment[a] and Session [b]																			
	SC				**SL**				**SI**				**MI**				**ML**				
Species	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**
Clethrionomys rutilus	11	17	41	47	0	7	23	25	14	54	87	83	19	23	22	20	2	20	36	66	42
Sorex sp.[c]	0	1	1	0	0	1	14	13	1	0	0	1	0	0	1	2	0	0	2	11	9
Mustela sp.	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1

	Total individuals for 1998 Season				
Clethrionomys rutilus	87	36	170	61	117
Sorex sp.	2	27	2	3	22
Mustela sp.	1	0		0	1

	Total captures for 1998 Season				
Clethrionomys rutilus	449	206	751	279	542
Sorex sp.	2	27	2	3	22
Mustela sp.	1	0	3	0	1

[a] Treatments are: SC = pure spruce no treatment; SL = pure spruce logged; SI = pure spruce infested; MI = mixed hardwood-spruce infested; ML = mixed hardwood-spruce logged.

[b] Sessions are: SC and SL (1) 5/24-5/28, (2) 6/15-6/19, (3) 7/7-7/11, (4) 7/29-8/2;
SI (1) 6/1-6/5, (2) 6/22-6/26, (3) 7/14-7/18, (4) 8/5-8/9;
ML (1) 5/17-5/20I (2) 6/1-6/5, (3) 6/22-6/26, (4) 7/14-7/18, (5) 8/5-8/9;
MI (1) 5/17-5/20, (2) 6/8-6/12, (3) 6/30-7-4, (4) 7/21-7/25.

[c] Specimens have to species. not been identified

Table 4 Individual captures of small mammals in logged, burned, and undisturbed mixed hardwood–spruce stands, and spruce bark beetle infested, logged, and undisturbed pure spruce stands on the Kenai Peninsula, Alaska, 1997

	Treatment[a] and Session [b]											
	SC		SL		SI		MC		ML		MB	
Species	Individual	Captures	Individual	Captures	Individual	Captures	Individual	Captures	Individual	Captures	Individual	Captures
Clethrionomys rutilus	124	406	70	323	48	144	28	75	26	96	14	31
Microtus sp.[c]	0	0	14	33	0	0	0	0	0	0	0	0
Sorex sp.	0	0	1	1	0	0	0	0	1	1	0	0
Tamiasciurus hudsonicus	0	0	0	0	n/a	5	0	0	1	1	0	0

[a] Treatments are: SC = pure spruce no treatment; SL = pure spruce logged; SI = pure spruce infested; MC = mixed hardwood–spruce no treatment; ML = mixed hardwood-spruce logged; MB = mixed hardwood-spruce wildfire burned.

[b] Sessions are: SC and SL 7/5–7/9/1997
SI and ML 6/12–6/17/1997
MC 6/24–6/29/1997
MB 5/24–5/29/1997

[c] Specimens have not been identified to species.

Table 5 *Clethrionomys rutilus* abundance per session on logged, infested, and undisturbed pure spruce and logged and infested mixed hardwood–spruce on the Kenai Peninsula, Alaska, 1998

	Treatment[a]									
	SC [b]		SL		SI		MI [b]		ML [b]	
Species	μ	SE	μ	SE	μ	SE	μ	SE	μ	SE
Clethrionomys rutilus	29.0	6.1	12.0	5.6	56.7	11.2	30.5	10.6	38.3	12.3

[a] Treatments are: SC = pure spruce no treatment; SL = pure spruce logged; SI = pure spruce infested; MI = mixed hardwood-spruce infested; ML = mixed hardwood-spruce logged.

[b] For statistical tests, means with same letter were not different (Multiple comparison ANOVA $P > 0.05$). LSD = 2.26.